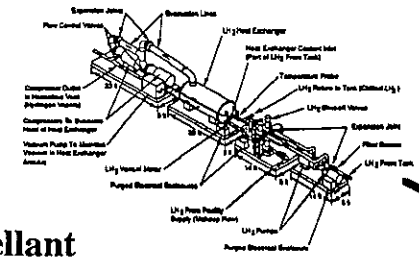
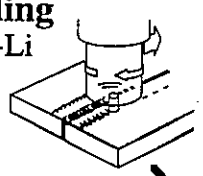
X-33 Rockwell Technology Demonstrations

Phase I

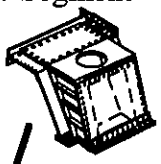


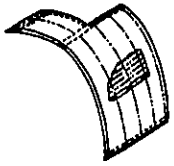
Propellant Densification

Friction Stir Welding
- Al-Li

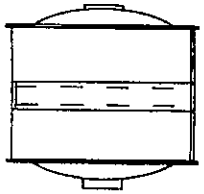


Composite Thrust Structure
- Full Scale Segment

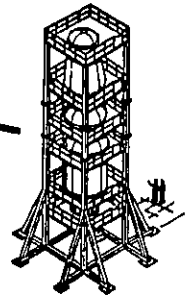




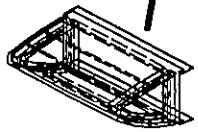
Composite Intertank
- Full Scale Segment



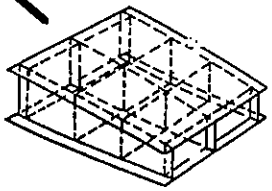
Composite LH_2 Tank
- Life Cycle Demo.



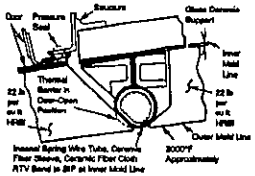
Integ. MPS



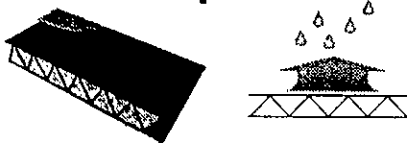
Tile Leading Edge



Composite Wing Section
- Full Scale Segment



Operable Joints & Seals



TABI TPS & Waterproofing

Informed Maintenance

Integrated Avionics

X 33

Reusable Cryogenic Tank System

Dan Dumbacher
May, 1995

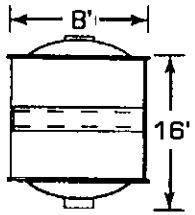
RLV Technology Status

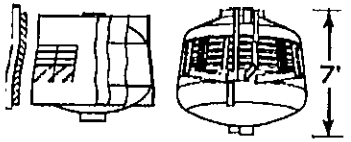
Reusable Cryogenic Tank System

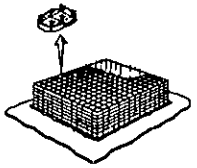
McDonnell Douglas

Major Products

	Description
• DC-XA Graphite-Composite LH_2 Tank System	• NASP Task D Tank Materials • Tank and Internal Cryogenic Insulation (3-D) • Hand Layup • Autoclave • Qualify Then Flight Test
• Composite Tank Component Level Tests	• Compatibility/Ignition Criteria • Permeability • Life-Cycle Test • Y-Joint Development • Stiffener Development
• Russian Al-Li LO_2 Tank System (2)	• 1460 Alloy • Tank and External Cryogenic Insulation • Ground: Integrate TPS Panels Life-Cycle Test • Flight: Qualify Then Flight Test
• Cryogenic Insulation	• External Foam Development – Reusability (Integrity, Adhesion, Cryopumping, etc.) • Internal Foam Development – 3-D (Saturn S-IVB) – Reusability (Integrity, Adhesion, etc.) – Inspectability • Integrate On Above Tanks
• Health Management	• Basic Characterization Tests on all Components (Fibers, Coatings, Sensors, etc.) Associated With Health Management • Integrated On Above: – Embedded Sensors – Data Processing System







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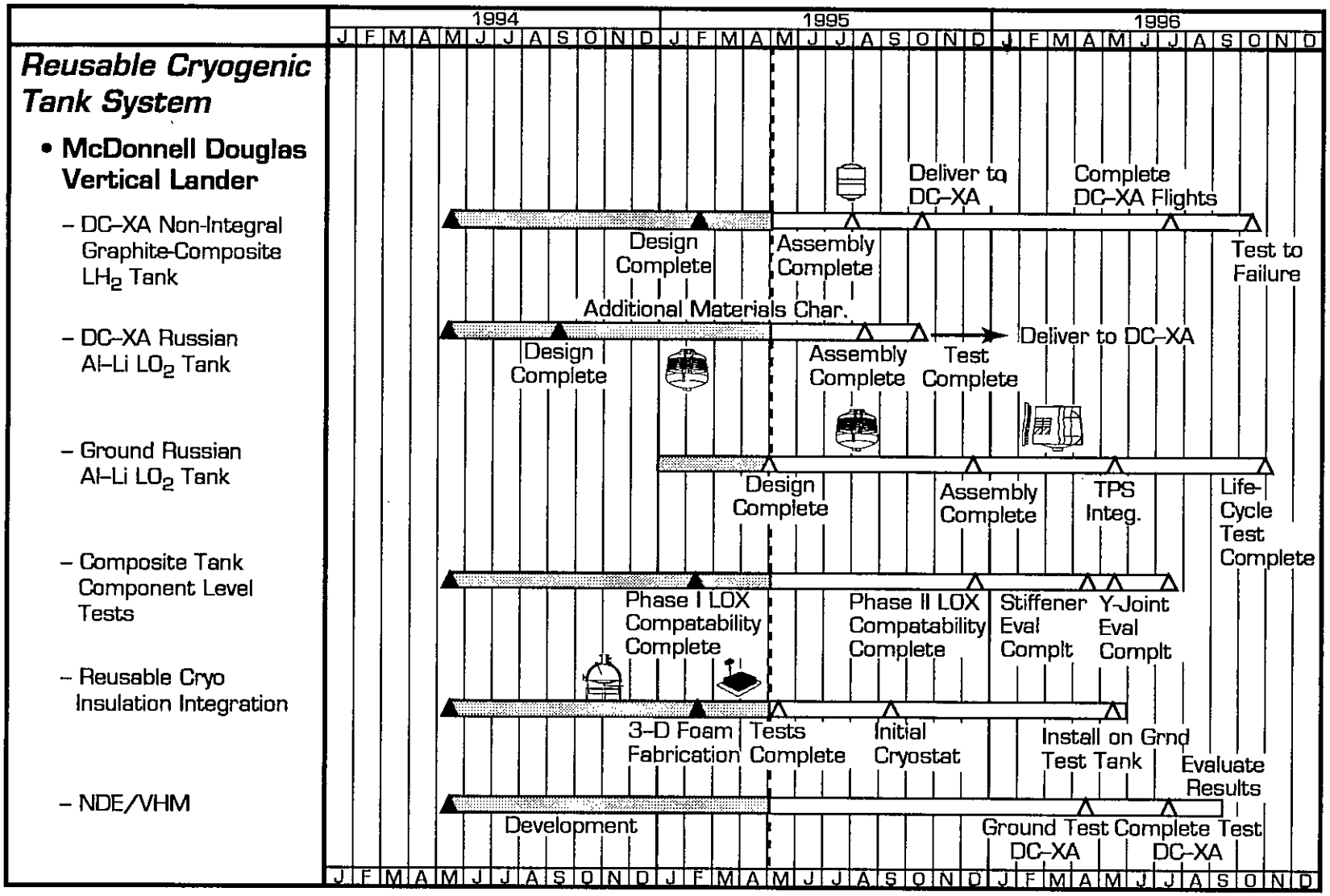
RLV Technology Status

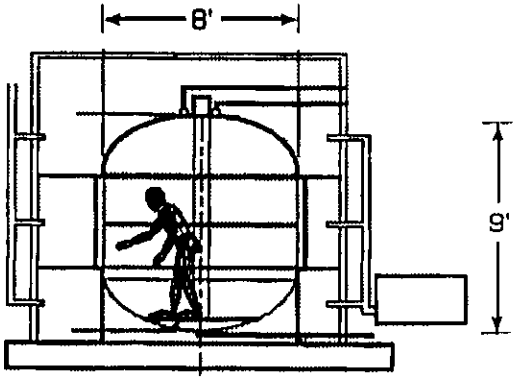


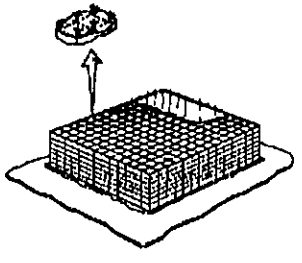
RLV Technology Status

Reusable Cryogenic Tank System
Major Products

Rockwell

	Description
• Graphite-Composite LH_2 Tank System	• Building Block Approach – Materials Development – Panels and Elements • 8-Foot Diameter Tank/Insulation/TPS Panels – Autoclave Versus Non-Autoclave – Automatic Fiber Placement • Life-Cycle Test
• Cryogenic Insulation	• External Foam Development • Process Development – Repairs, etc.
• NDE/Health Management	• Screen Equipment and Sensors • Integrate on Above Test Article





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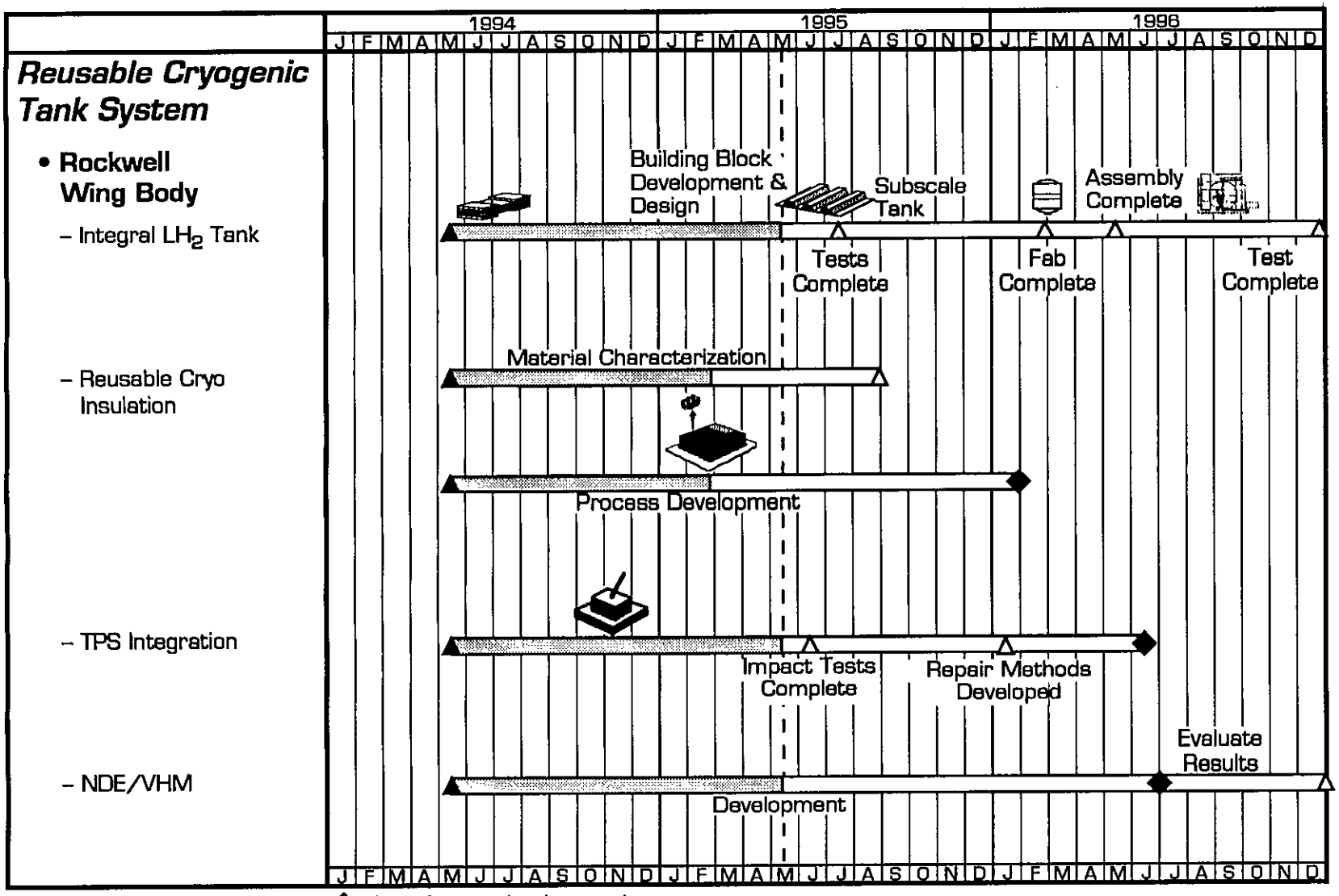


Composite Primary Structures

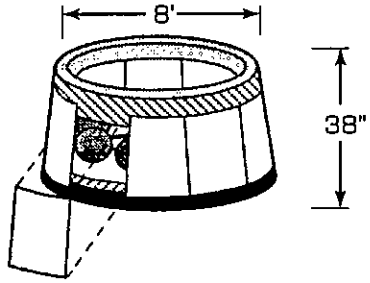
Dr. Charles Camarda
May, 1995

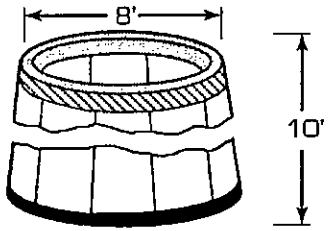
X 33 Advanced Launch Technology Status

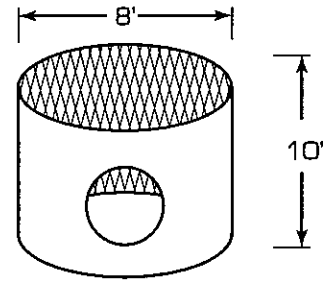
Graphite-Composite Primary Structure

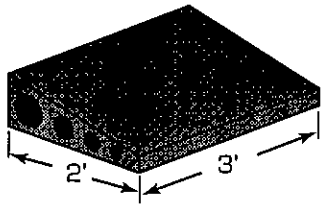
McDonnell Douglas

	Description
• DC–X Intertank	• Cyanate Ester Composite • Shell Construction • Cryogenic Interface • Qualification Test
• Conical Ground Test Intertank	• 1/4 Scale of DC–Y • Skin-Stringer • Doors, Cryogenic Interfaces • Integrate TPS • Combined Loads Testing (Life Cycle) • Quartz Lamps Testing • Damage Tolerance
• Russian Isogrid Intertank – Academy of Sciences	• Same Except Isogrid • Filament Wound • No TPS
• Control Surfaces – Ceramic Matrix Composite (CMC)	• Scale Component • Elevon or Tip Fin • High Temperature/Light Weight • Structural Performance









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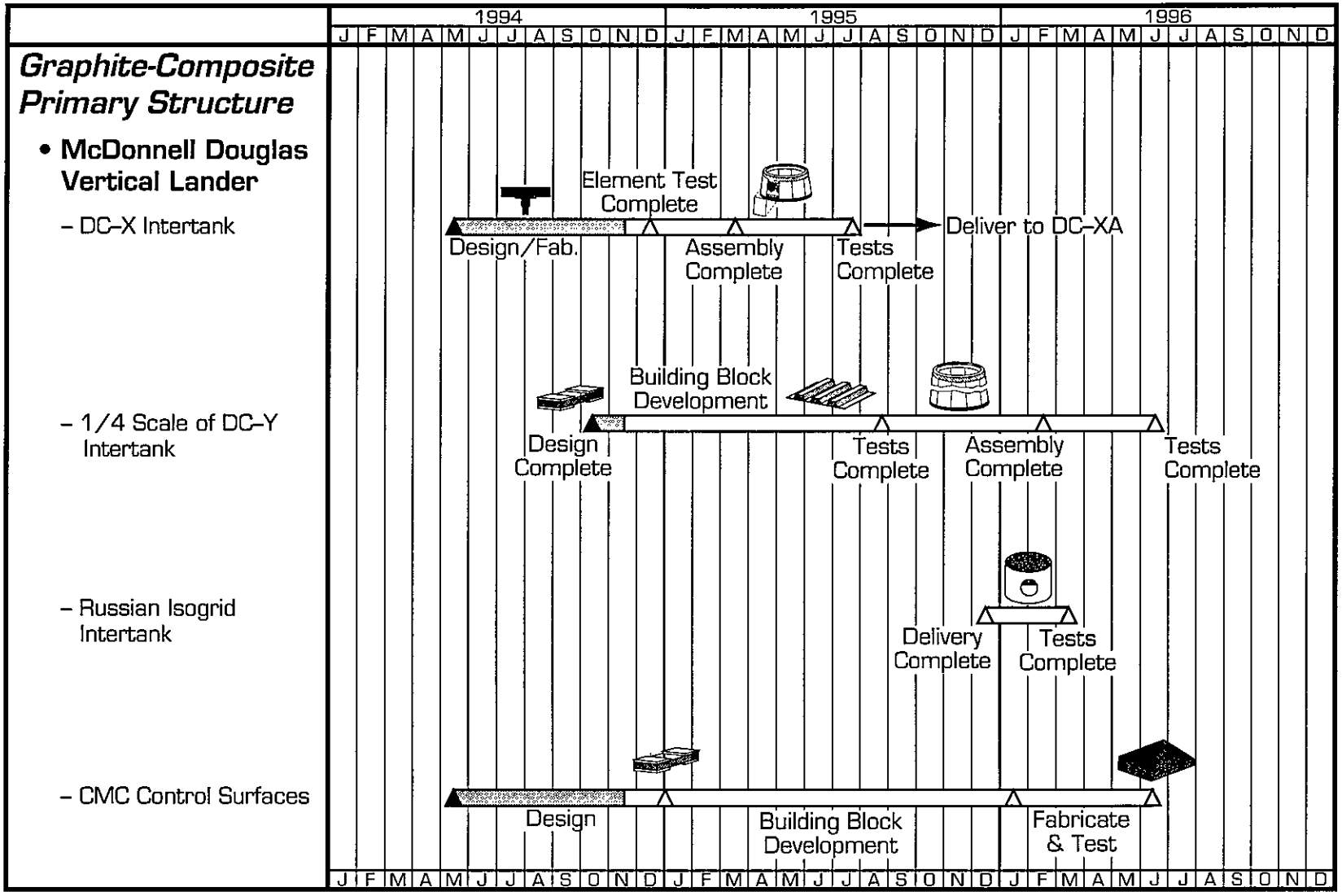
RLV Technology Status

Advanced Structures and TPS Technologies



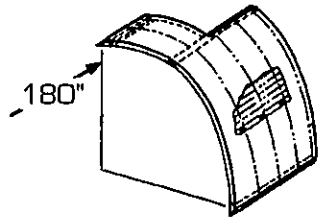
X-33 Advanced Launch Technology Status

Graphite-Composite Primary Structure

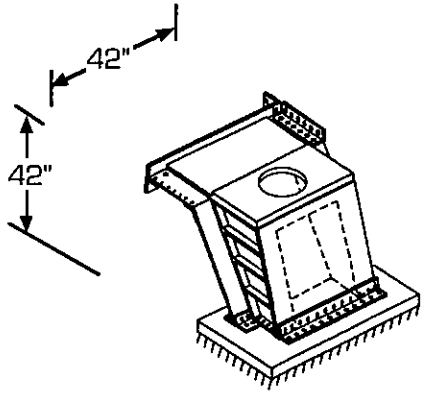
Rockwell

Description

- General
  - High-Temperature Polyamides (AFR–700, etc.)

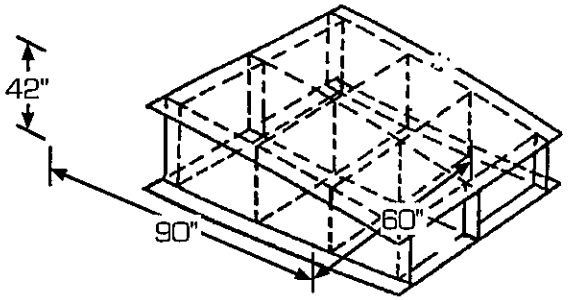


- Intertank
  - 1/4 Segment of Full Scale Rockwell SSTO
  - Doors, Cryogenic Interfaces
  - Combined Loads
  - Damage Tolerance
  - Integrated Health Monitoring



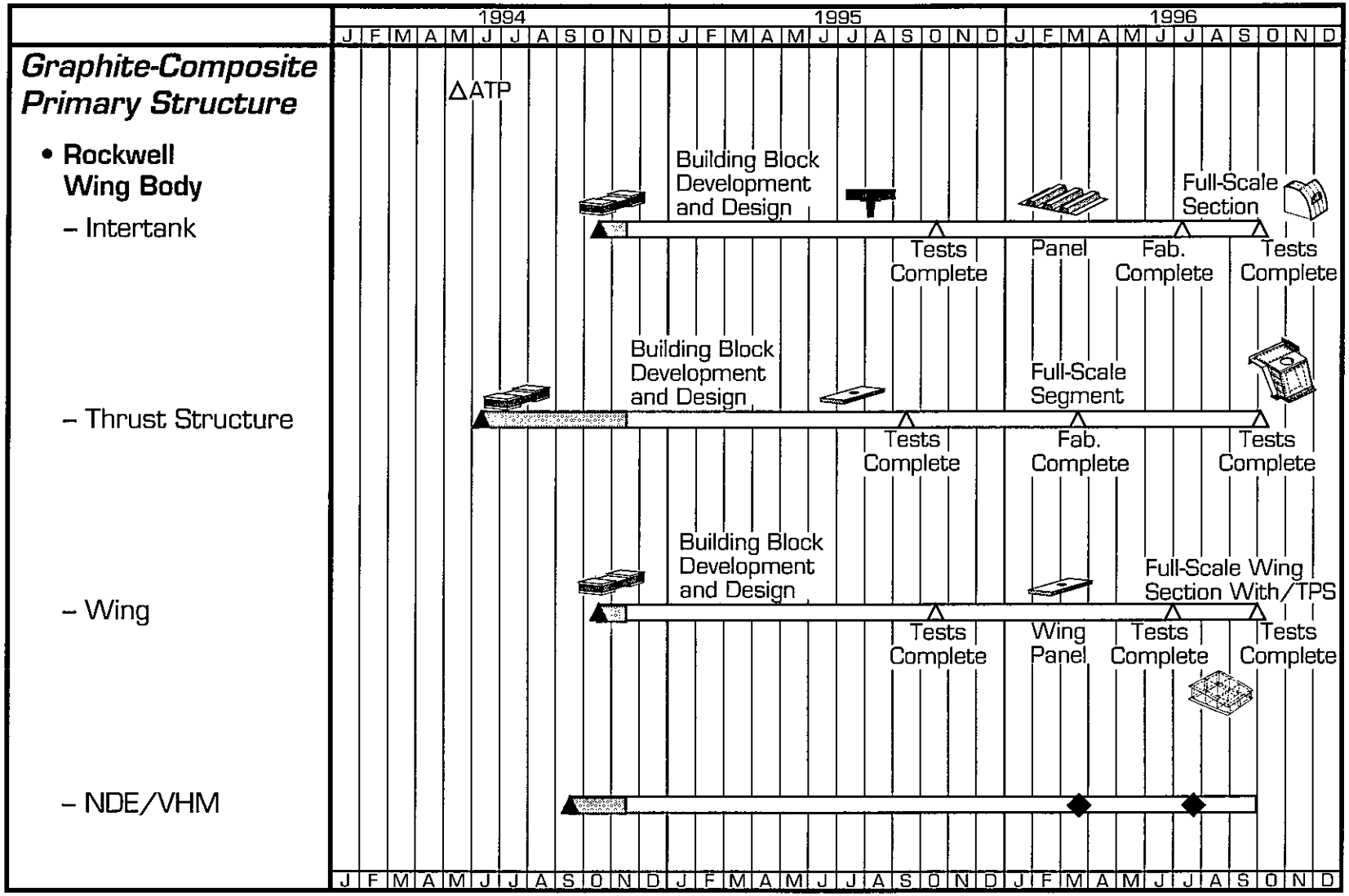
- Thrust Structure
  - Segment of Full Scale Rockwell SSTO
  - Engine Mount
  - Fiber-Toughened Composites/Pultruded Rod Racks
  - Integrated Health Monitoring
  - Acoustic and Combined Loads
  - Life-Cycle Test and Test to Failure (2 Articles)
  - Damage Tolerance

- Wing
  - Wing Box Section of Full Scale Rockwell SSTO
  - TPS Integration
  - Wing/Tank Interface
  - Integrated Health Monitoring
  - Combined Loads
  - Damage Tolerance



RLV Technology Status

Advanced Structures and TPS Technologies



Thermal Protection Systems

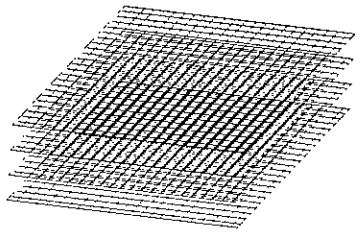
Steve Cook
May, 1995

X-33 Advanced Launch Technology Status

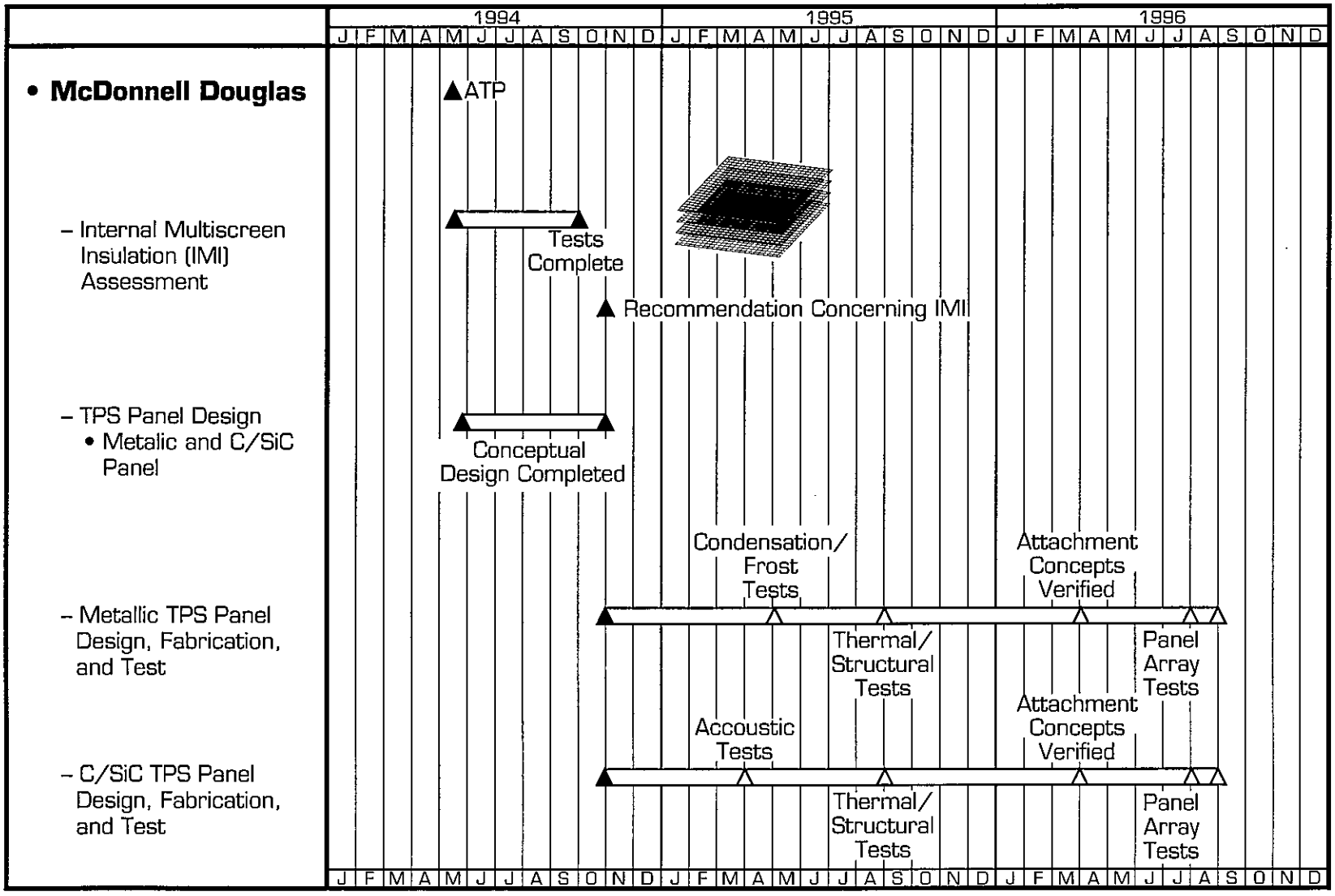
Advanced Thermal Protection Systems

McDonnell Douglas

	Description
• Internal Multi-Screen Insulation (IMI) – MAN Technologies (HERMES)	• Verify Concept • Thermal/Acoustic, and Humidity Testing • IMI Assessment Decision
• TPS Panel Design	• Conceptional Design
• Metallic Prepackaged TPS	• Design, Fabricate, and Test TPS Panels • Coatings (AS&M) • Thermal Performance Testing (Arc-jet) • Environmental Testing (Acoustic, Wind/Rain, Frost/Ice, Impact) • Fail-Safe Attachments • Single Panels and Arrays Integrated With Cryotank/Structure
•C/SiC Standoff TPS	• Design, Fabricate, and Test TPS Panels • Environmental Testing (Acoustic, Wind/Rain, Frost/Ice, Impact) • Fail-Sage Attachments • Single Panels and Arrays Integrated With Cryotank/Structure
• NDE/Health Monitoring	• Integrate With Above Tests



Thermal Protection Systems Technologies

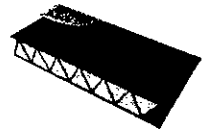


X 33 Advanced Launch Technology Status

Advanced Thermal Protection Systems

Rockwell

	Description
• Fluted Core Flexible TPS Blankets – With Textile Products	• TABI – Reestablish Manufacturing • Thermal Performance Tests (Arc-jet) • Environmental Testing (Vibro-Acoustics, Wind/Rain, Frost/Ice, Impact, Repaired Panels)
• Advanced Flexible TPS With Multi-Layer Insulation	• Radiation Shield • CFBI • Same Tests as Above
• Waterproofing	• Rigid and Flexible TPS – Low-Cost/Manpower Techniques to Re-Waterproof – Environmentally Acceptable – Significant Effort Also In-House
• TPS Attachment Techniques	• Direct Bond (Strain Isolation Pad) • Velcro • "Top Hat" Cover to Tiles • Integrated With Above Tests
• NDE/Health Monitoring	• Integrated With Above Tests • Flaw Detection and De-Bonds • Integrity • Water Content • Integrate With/Cryo Tank and Composite Structures



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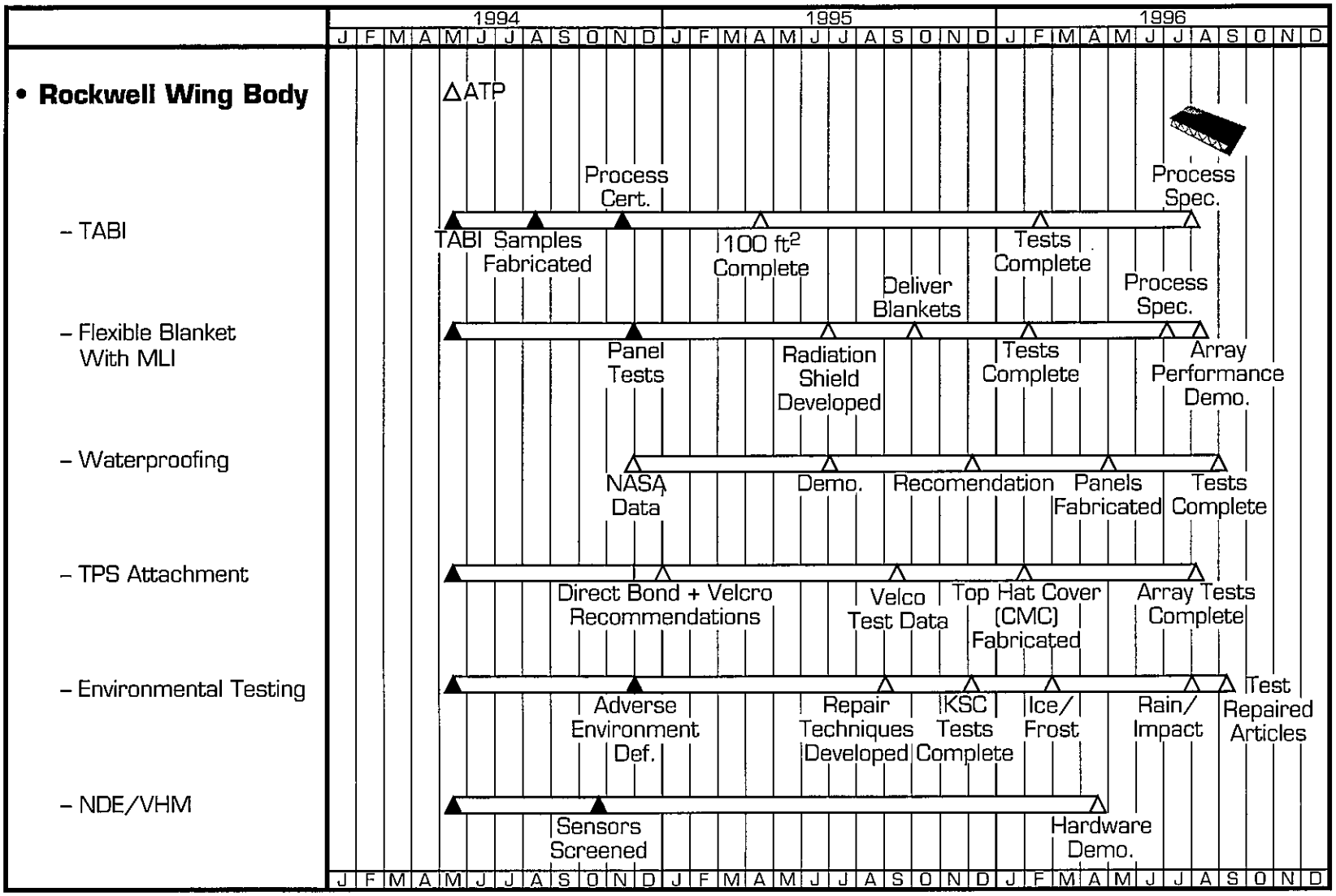
Thermal Protection Systems Technologies



X 33

X-33 Task 4

Complementary Technology Demonstrations

Steve Cook
May, 1995

Technology Demonstrations

Objective:

- **Focused Technology Demonstrations that are Requried to Achieve a Successful X-33 / RLV Concept Downselection & Phase II Initiation**

  - Major Products Complete in 15 mos. (Prior to Downselect)

- **Tasks in Addition to On-Going Technology Demonstration Efforts**

  - Several Industry Wide Reviews Prior to CAN Release
  - Fill the Technology "Gaps" as Viewed by Industry Partners
  - Limited to Task 1-3 Selectee's (Concept Design)*: Focused Technology*

- **Selection Criteria Categories / Priorities**

  (1) Configuration Specific Technologies
  (2) Configuration Independent, Enabling Technologies
  (3) Configuration Independent, Enhancing Technologies

Selected Task 4 Demonstration Areas

- **Operations**
  - Integrated Avionics/GN&C
  - Integrated Vehicle Health Management
  - Adaptive / Automated Mission Design/Planning
  - Autonomous Abort
  - Informed Vehicle Maintenance
  - EMA's & Power Sources

- **Reusable Cryogenic Tank System**
  - Lined Gr-Ep Tanks & Insulations
  - K3B Thermoplastic Tanks

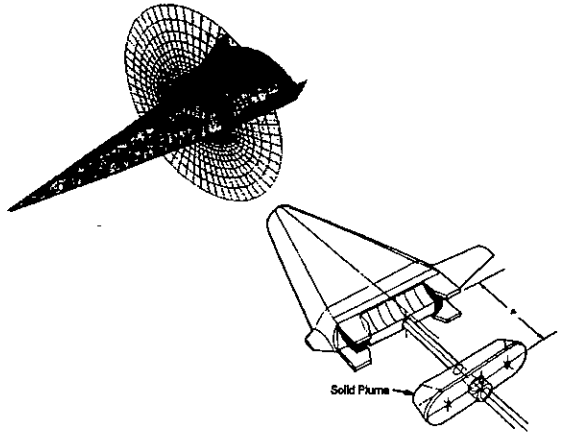
- **Thermal Protection Systems**
  - Leading Edge & Durable Thermal Seals/Barriers
  - Metallic TPS
  - Mechanical Attachments

- **Propulsion**
  - Integrated Lifting Body/Aerospike Cold Flow Wind Tunnel & CFD (complementary to SR-71 hot fire)
  - Thruster Fabrication
  - Dual Bell Nozzle (CFD)

X-33 Lockheed Martin Demonstrations

Linear Aerospike Verification
- Verify Integrated Lifting Body/ Engine Aero Characteristics and Performance Effects on Engine

- **CFD**
  - **Vehicle Flowfield**
  - **Model Support**
  - **SR-71 Support**
- **Wind Tunnel (Cold Flow)**
  - **Solid Plume (0.4% Scale)**
  - **Slipstream (2.2% Scale)**



Linear Aerospike Engine Enhancements
- Low Cost Thruster Mfg. Process
- Showerhead: Low Torque (36:1 reduction)
- EMA: Operability

- **Engine Modular Thruster (2)**
  - **HIP Bonding Process**
  - **Hot Fire Test**
  - **Round-to-Rectangular Exit**
  - **Designed for X-33**

- **EMA Propellant Valve**
  - **Full Scale, Flight Weight**
  - **Req'd for Differential Throttle**
  - **Designed for X-33**

Electric Actuation
- Operability
- Complements On-Going ELV Work w/ Focus on Power Sources

- **Control Surfaces and Propellant Valve Actuation Req'ts**
- **Test Battery and Super Capacitor Designs (w/ LeRC ELV Actuator)**
- **Detailed Simulations to Bridge Results to LADC SSTO Concept**